蔬菜作物之族群改良實例

盧 煌 勝
台灣省農業試驗所農藝系

前 言

作物之改良方法甚多，在族群改良之應用上，約可分成二類，一為强調於單一族群之改良，如混合(mass)、異親兄妹(half-sib)及同親兄妹(full-sib)及自交後裔(selfed progeny)等之輪迴選種法皆為族群內改良(intrapopulation improvement);另一為强調於族群雜種之改良，如異親兄妹相互輪迴選種法 (half-sib-reciprocal recurrent)、同親兄妹相互輪迴選種法 (full-sib-reciprocal recurrent) 等均為族群間改良(interpopulation improvement)。選種效應視選拔方法、選拔强度、對象族群以及測試親等之不同，而有相當不一致的結果。本文僅就蔬菜作物之族群改良實例加以說明，資料主要取自 Kalloo 所編之蔬菜育種書上(70)。另外，補充在文後之許多文獻，將提供有興趣從事族群改良工作的讀者作進一步的參考。

混合選種

混合選種的方法可以應用在自交(self-fertilizing)及異交(cross-fertilizing) 之蔬菜作物。通常，根據外表型，從一品種之異結合族群(heterogeneous population)中選出優良植株，再將選株之種子混合在一起，此一族群就成為近似純系之混合體 (mixture of almost similar pure lines)。具高遺傳性之性狀，不易受環境影響，混合選種的成效較大。 但當族群的變異性已經很小，混合選種的成效則相對地變小。

混合選種的過程，乃是將選獲之種子種植於隔離區中，並令其天然授粉(open pollination)。從族群中選出 5～10%最高產量之植株， 再由每一選株取出等量之種子混合以為下一世代所需之種子。每年重複這些相同之步驟。在每一循環選拔中可與原始品種進行產量比較試驗，以評估選拔效果。

由於作物近親交配劣勢 (inbreeding depression)的現象非常普遍，因此所選植株的最少量也必須有所限制。一般而言，如果所選植株數太少，產生的族群就容易很快地即有退化的可能。依作物種類、近親交配劣勢的程度以及自交不親和性(self-incompatibility)的反應而定，通常所選植株數最少不得低於20～25。一般實施混合選種並沒有作後裔檢定(progeny test)，自花授粉作物行後裔檢定，及由其衍生之各後裔繼續研究遺傳及育種行為，可以評估出選株之基因型，以了解選株是同型結合性(homozygosity)或異型結合性(heterozygosity) 。

藉由混合選種來達到品種改良的目的蔬菜有：菠菜、甜菜、十字花科作物、根類作物、葫蘆

及甘藷等。對菠菜而言[120]，混合選種是育成新品種很常用的方法。 由於雌株比雄株具較大的生產力，因此選擇雌株即可增加雌雄比例。另外，於英國國立蔬菜試驗場(NVRS)，Wellesbourne地區，研究人員利用混合選種及後裔檢定，育成抗抽苔 (bolt-resistant)的甜菜新品種[29,52]。亦曾有人利用混合選種法增加花椰菜之外部苞葉數目，以提高花蕾(curd)的品質。McNaughton[96]及Johnston[65]也提出採用混合選種法來改良蕪菁(swede, *B. napus* ssp. *rapifera*)。洋蔥改良方面， Arka Kalyan ， Arka Niketan ，及 Arka Pragati等品種即是利用混合選種法分別自11HR145，11HR153，及 11HR149 等選育而成[25,97]。經由獲選植株之混合授粉，McCollum成功地育成韮蔥新品種[94]。

藉由混合選種，ajowan之族群平均產量由P_0 至P_1及P_2，均有明顯的提昇。其法乃自1,000植株之原始族群開始，選拔強度爲30%，Andrus and Bohn[1]也提出應用此法達成甜瓜之改良報告，這些結果均說明了作物藉混合選種法可達到相當程度的遺傳改良效果[117]。

混合選種也曾用在甘藷的改良工作上[66]，應用此法乃基於其對染色體間以及染色體內之重組合 (intra and interchromosomal recombination) 可作最大的利用。此育種方法乃從基礎族群的形成(formation of a base population)開始進行，首先選出4至20個親本，令其充分互交(intermate)。第一世代的種子等量混合之後，至第三世代均利用隔離區經由昆虫媒介作逢機交配。從F_4開始進行選拔，而選株的數目則視需要及改良目標而定。所選植株可進行評估、增殖或提出命名推廣栽培之用(如圖1)。

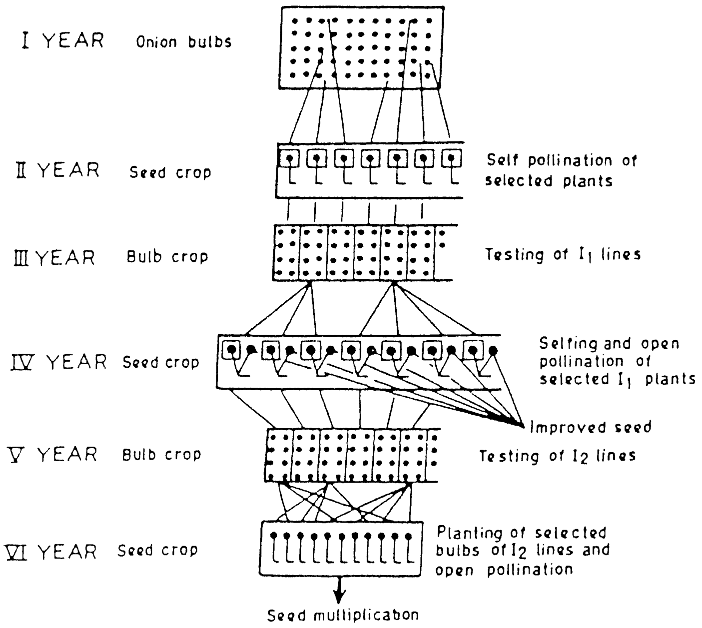

Fig. 1. Selfing and massing scheme for the improvement of *Allium cepa*.

甘藷混合選種族群或多邊雜交苗(polycross nurseries)，可種植於隔離區，任其天然授粉。每一循環之推進，由種子的種植至下一代的種子產生，並不進行選拔。當然，此過程中尚可就

篩選某些抗虫性、抗病性及貯存特性(storage characteristics)等作必要之修改，而成爲每兩年一循環[69]。混合選種已經被廣泛的應用來結合多種抗病、抗虫、抗線虫及其他重要園藝性狀[30,67]。對異花授粉作物而言，根據外表型選拔眞正優良的植株，再混合獲選植株之種子，當可維持作物之純度及優異性，而將不良植株不斷地剔除去。

後裔檢定及系統育種

對於異花授粉之蔬菜作物，尤其是十字花科、根類作物及甜玉米，由於這些作物大多數的植株都是異型結合體(heterozygous condation)，因此透過後裔檢定來選擇植株即很重要。於此情況下，將一植株之後裔種成一行，以檢定其育種行爲，植株之優異性不管是由於遺傳變異(genetic variation)所使然或者是環境效應 (environmental effects)，皆能經由後裔檢定予以洞悉。性狀優異且相似之後裔系統即可組合在一起。此法亦稱之爲系統育種法、或株行選拔法(plant to row selection)、或穗行選拔法(ear to row selection)。Horne在花椰菜之育種工作中，即依後裔檢定結果，進行選拔及混合授粉，終於育成優良新品種[54]。

族 系 育 種 法

族系育種法的程序，除了必須進行不只一個循環以上之選種外，都與系統或穗行或株行法相同。此法對改良胡蘿蔔、白蘿蔔、蕪菁均非常有效。偶爾，此法也用來改良花椰菜、甘藍、球莖甘藍、抱子甘藍、綠葉甘藍及青花菜等。此法包括：從一基礎族群選拔植株、生產選株之種子、後裔檢定而後組成合成品種(synthetics)。第一年由基礎族群挑選出優良植株，並藉由天然授粉、自交、配對雜交(pair cross)、全互交(diallel cross)及頂交(top cross)等方式生產種子。第二年針對選株之表現進行試驗，選出優良品系。第二年試驗結果，將獲選族系之根、花蕾、球(head)等，分爲二部分，一部分採用第一年相同的方法繁殖種子，另一部分則用以產生合成品種。同樣的過程重複進行，直到預定目標達成爲止[129]。利用後裔檢定以選出各別植株再加以混合，是族系育種法常見的特色。此法不需組合力檢定，但爲之亦無不可。某些修正之方法中，在較高世代，即將許多品系與一檢定親(tester)雜交，再進行評估、選拔。有些例子裡，也利用多邊雜交檢定選出優良系統，而此法或比前面所提方法爲佳。另外，亦有將所有選系種植在一起，任其逢機授粉。圖2 爲利用族系育種法改良白蘿蔔之過程。族系育種法可伴隨各種不同之後裔檢定，如天然雜交、自交、全互交、多邊雜交、頂交等等，進行年復一年的循環改良工作。

輪 迴 選 種

輪迴選種可促使族群內達到相當高程度的遺傳變異性(genetic variability)，增加有利基因間之重組(recombination)機會，並打破族群中不利之連鎖(undesirable linkage)現象。由於輪迴選種可以維持族群內頗高之遺傳變異性，增大族群內之改良空間，因此，輪迴選種應爲一頗具潛力之選拔方式。而輪迴選種的選拔效果則視基礎族群及其基因頻度、選拔强度、以及異質雜交(inter-crossing)情形而定。一般而言，其方法包括選擇具有較廣遺傳背景的族群(broad-based genetic populations)開始，同時於兩族群間作頻繁之交配。不管是行天然的逢機交配或人

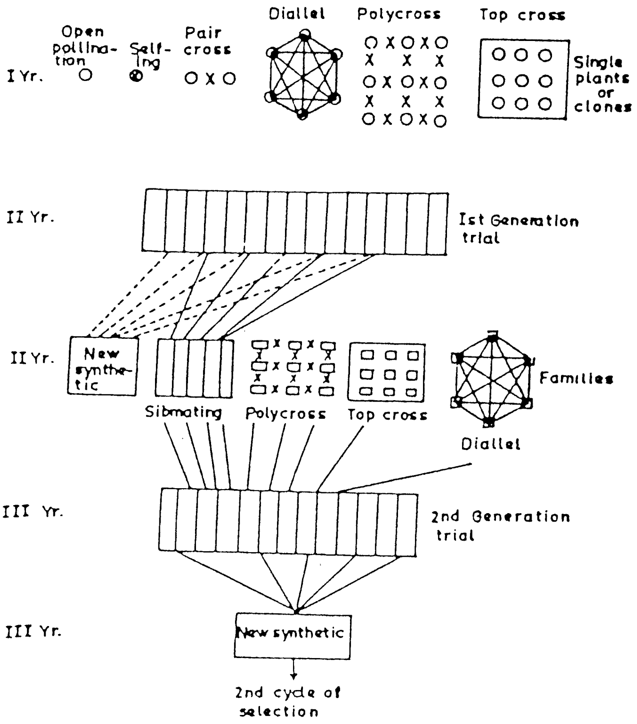

Fig. 2. Family breeding method (From Swarup. V., Indian Council of Agricultural Research, New Dethi, 1977. With permission.)

爲的雜交，均是自交作物採用輪迴選拔法之主要限制因素。

具較廣遺傳背景的族群，或爲F_2、或爲複交雜種(multiple hybrid)、或爲一已改良的族群。數種交配設計可以應用以產生多種不同型式之基礎族群。一般而言，基礎族群係經由一些特定的親本進行多重雜交來產生。譬如，假使想由八個親本來組成一個基礎族群，下列之交配方法可爲一種參考方式：

A × B　　C × D　　E × F　　G × H

↓　　　　↓　　　　↓　　　　↓

F_1 × F_1　　　　F_1 × F_1

↓　　　　　　　　↓

F_1　　　　×　　　　F_1

↓

F_1

↓

F_2　　　Base population

8個親本先兩兩雜交產生4個單交F_1組合(single cross F_1)。一個雜交組合的F_1又與另一個雜交組合的F_1再雜交，產生 2個雙雜交F_1族群(double cross F_1 population)，此2個雙雜交的F_1

族群再雜交，就產生具有所有親本遺傳質的族群。此一族群即可用來作爲基礎族群。

1.簡單輪選種(Simple Recurrent Selection)

簡單輪迴選種之第一年，選出許多優良植株並令其自交。獲選植株之自交種子於次年種植並使其任意互交。收穫互交植株上之種子，於次年栽種以進行第二個循環之選拔。第二個循環開始，復選出優良植株令其自交，再將自交種子於隔年栽種成行完成選株間之互交。這些步驟重複進行，直到基因頻度已達某一理想目標爲止。

在少數的例子裡，如果植株之優良性狀可在開花之前予以評估，那麼，可以逢機選定優良植株，並任其自由配對雜交。雜交種子於次年種植，並繼續進行選株間之互交。如此，即可完成一個循環之選株間的互交，而僅須經過數個循環的互交，即可達到一定程度的改良成果。

對於自花授粉作物而言，欲完成互交工作確是一大困難。爲了克服此一困難，一些植物之異花授粉機制，譬如，雄不稔性，即被拿來應用。在番茄、胡椒、大豆[12·13]及豇豆[116]等，均曾有成功之例証。此法對基礎族群之組成及促進選株間之互交皆有極大的用途。另外，Compton[15]建議大豆利用單籽後裔法(single seed descent SSD)可以減少過量的雜交工作。在此方法裡，藉由SSD法，每一品系是衍生自不同的F_2，而不是單一雜交之不同F_2植株，此過程只需要200至400個人工雜交授粉。

2.一般組合力及特殊組合力之輪迴選種法 (Recurrent Selection for General Combining Ability and Specific Combining Ability)

特殊組合力之輪迴選種法是由 Hull[56]所提出，其法乃爲了能夠產生具有良好的雜交組合品系而設計的，其步驟如下:

(1) 第一年，從一族群中進行選株，每一選株須行自交，同時與一同型結合的檢定親行雜交，以進行品系間之特殊組合力測試。

(2) 測交種子用以進行多重複之比較試驗。根據試驗結果，選拔特殊組合力强者。

(3) 測交種比較試驗中表現良好的選系，將其第一年的自交種子予以種植，並令其作最大可能之異交。

(4) 由上述各種異交組合產生的種子，混合而成新族群，即可進行次一循環選拔工作。依次，第一年中被選植株行自交並與一同型結合檢定親雜交，相同的步驟重複進行著。

一般組合力之輪迴選種係由 Jenkins[60]所提出，此法的優點是基因頻度將朝理想方向漂移。其進行步驟與特殊組合力之輪迴選種法相同。所不同的是，與獲選株進行雜交者爲一異型結合之檢定親。

3.相互輪迴選種(Reciprocal Recurrent Selection)

相互輪迴選種法提供同時改良一般組合力及特殊組合力之機會。若族群A及族群B被選爲進行此一選種法之材料，此兩族群則分別作爲另一相對族群被選植株之檢定親。第一年族群A及族群B分別種植，於族群A選出一些植株令其自交，同時與B族群選出之植株雜交。於族群B 進行相同之步驟。第二年，進行多重複之測交種比較試驗。第三年，將根據第二年測交種比較試驗結果，選拔優良植株並將其第一年之自交種子種植在二個隔離之雜交區，令其充分雜交。每一族群分別收穫混合，即完成第一次循環之選拔。第四年，兩個新混成的族群 A及

B 分別種植，再重複第一年之工作。第五年、第六年分別重複第二及第三年之步驟。同樣地，第六年即可完成第二循環之選拔。

由此選拔方法產生的兩族群，將較其原始族群(original population) 更爲高產；同時，亦能利用其作雜交，以進一步產生遺傳基礎更廣之優良族群。相互輪迴選拔的成效，亦受基礎族群之基因頻度所影響(18)。

採用輪迴選種法改良之蔬菜作物有菜豆、大豆、番茄、茄子、根類作物、十字花科作物及甘藷等。輪迴選拔中之基本遺傳材料關係著整個選拔過程的成敗。於番茄育種中，相互輪迴選拔的效率視所使用的品種間雜交種(intervarietal hybrids)而定。在Niger地區，1965～1975期間此法亦被用在洋蔥之改良。其過程包括簡單輪迴選種與選系間混合授粉及後裔檢定等之相互交替運用。於熱帶地區，此法亦是改良洋蔥的最有效方法之一。菜豆基礎族群於開花前進行選株，而後於選株間相互雜交，如此所進行之輪迴混合選種，在經過二個循環後，已使種子蛋白質含量由21.9 %升至24.6 %(128)。 大豆經過三個循環之選拔，其產量已顯著改善(72)。兩個胡瓜族群，一爲純雌株合成品種(gynoecious synthetic)及另一 HSE族群，進行特殊組合力之輪迴選種及同親兄妹族系選種 (full-sib family selection)。經過二個循環之後，單株果實數及產量均已明顯增加(76)。

Barnes and Cuthbert 運用輪迴選拔法育成抗蚜蟲之蕪菁品系(9)。產量高及質地優之 calabrese 新品種亦由 Dhankhar 以此法育成。在花椰菜方面，花蕾大小影響產量與品質至鉅，而此二性狀深受累加效應所左右，輪迴選種法適可發揮作用而達到改良之效果。在輪迴選拔過程中，高度自交不親和品系可以用來增加異結合的比率。輪迴選種及後裔檢定可進行相當多的世代，而自交不親和性適足以迫使異交之進行。自交不親和性的程度也可經由選拔而改變(23·41)。輪迴選種在玉米產量(83·95)、馬鈴薯抗熱性(37)、甘藷抗疫性(26)及茄子抗*Verticillium*(105) 等均有相當成功的例子。利用輪迴選種法，結球白菜族群在球重、早熟性及植株重等已有顯著的改良。 Yoon and Opena 認爲一般組合力輪迴選種法對結球白菜族群之進一步改良亦見效益(137)。

二年生的十字花科作物及根類作物在選拔及授粉上提供了較爲有利的機會。不論花蕾、球、根部或植株均可在成熟期作必要的檢視，而後選出理想的植株栽種來進行雜交、互交及繁殖種子。

自花授粉與混合授粉

此法首先選出合於理想性狀之鱗莖，令其植株自交以增加性狀之整齊度及產生不分離系 (true breeding line)，然後再行混合授粉以恢復生長勢。 Jones 及 Mann(68)將改良洋蔥之程序說明於圖3。第一年：選出100個鱗莖作爲單獨系統之親本。第二年：每一植株之部分花序令其自交。第三年：檢定所有自交系統之後裔，收獲其自交種子(I_1 line)，並分別種植。再由每20～30個優良系統中選出15～20個最佳之鱗莖。第四年：種植第 3年所選之鱗莖，每一植株的一半花序進行自交，另一半則使其混合天然授粉。自交不得多於二次，否則會減少種子產量。混合天然授粉可保証種子之優良品質及避免自交弱勢之發生。第五年：種植第 4年自交植株(I_2 line)的種子，同時自25個最優良系統中選出15～20個鱗莖。第六年：選出之鱗莖種植於隔離田，任其

天然授粉，種子混合收穫，並繼續以天然雜交方式大量繁殖種子。

近親交配與選拔之同時運用，對花椰菜的整齊度及生長勢作了相當大的改良[38]。一般而言，選拔性狀及選拔方法乃由育種目標所決定。不同作物種類即有相當不一致之選拔性狀，如 calabrese 之整齊結球；花椰菜之整齊度、緊密性、色白及自動內捲性；甘藍之早熟性、緊密性、整齊球及球型指數；芹菜之抗幼苗抽苔及減少纖維成分；胡蘿蔔之整齊度、self colored core、少纖維、splitting 及高胡蘿蔔素；蘿蔔及蕪菁之高產量，及減少髓部組織；菠菜之延遲抽苔、葉質改良及暗綠色葉；洋蔥之高產、整齊、窄頸及良好的耐貯存性；甜菜根狀大小之整齊性、抗幼苗抽苔等等性狀。

對菠菜而言，早熟性是一重要特徵。而此特徵又與抽苔率及植株之生長有關。早熟性與產量極具關係，選拔某一性狀將附帶影響其他的性狀，早熟性同時易受環境因子所左右。因此，選拔或應根據葉原體(leaf initiation)爲標準，而不要根據易受光週性改變的抽苔性狀[109]。

American Seed Trade Association and Barnes 對美加地區藉各種不同育種方法育成的蔬菜品種有很詳細的報導[6·7·8·84·85]。此外，尚有許多有關蘆筍、十字花科、胡瓜、蘿蔔、朝鮮薊等之改良，亦可由 Corriols[21]，Honman[53]，Baggett[2]，Crisp *et al*[24]，Pyo[115]，Tulupova[113]，Yoon and Lee[137]，Nienhuis[106]，Lertrat and Lower[77·78]，Banga[3]，Watts[135]，Banga and Bennekom[5]，Ryder *et al*[121]等報告中參考。目前，蔬菜育種工作的問題、重要性及成就已受到相當的重視[4·57·58·113·114·136]。

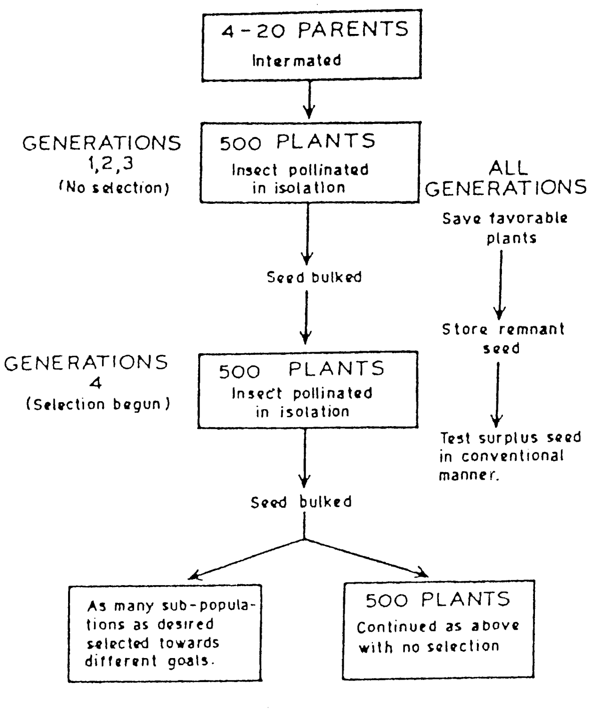

Fig. 3. Mass selection method in *ipomoea batatas* (From Jones, A., Crop Sci., 191, 1965. With permission.)

參 考 文 獻

1. Andrus, C. F., and G. W. Bohn. 1967. Cantaloup breeding : Shifts in population means and variability under mass selection. Amer. Soc. Hort. Sci. 90 : 209.
2. Baggett, J. R. 1976. Oregon CR-1 broccoli. HortScience 11 : 622.
3. Banga, O. 1954. Taproot problems in the breeding of root vegetables, Euphytica 3 : 20.
4. Banga, O. 1957. Horticultural plant breeding in the Netherlands. Euphytica 6: 11.
5. Banga, O., and J. L. Van Bennekom. 1962. Breeding radish for winter production under glass phytoron investigation for the development of a selection method. Euphytica 11 : 311.
6. Barnes, W. C. 1969. New vegetable varieties list XVI. HortScience 4 : 65.
7. Barnes, W. C. 1970. New vegetable varieties list XVII. HortScience 5 : 146.
8. Barnes, W. C. 1971. New vegetable varieties list XVIII. HortScience 6 : 124.
9. Barnes, W. C., and F. P. Cuthbert. 1975. Breeding turnips for resistance to the turnip aphid. HortScience 10 : 59.
10. Bohn, G. W., and C. F. Andrus. 1969. Cantaloup breeding : Correlations among fruit characters under mass selection. USDA Technical Bulletin 1403 : 1.
11. Brim, C. A. 1966. A modified pedigree method of selection in soybeans. Crop Sci 6 : 220.
12. Brim, C. A., and C. W. Stuber. 1973. Application of genetic male sterility to recurrent selection schemes in soybeans. Crop Sci. 13 : 528.
13. Brim, C. A., and M. F. Young. 1971. Inheritance of a male sterile character in soybeans. Crop Sci. 11 : 564.
14. Colbert, L. L., L. L. Darrah, and M. S. Zuber. 1984. Effect of recurrent selection for stalk crushing strength on agronomic characteristics and soluble stalk solids in maize. Crop Sci. 23 : 473.
15. Compton, W.A. 1968. Recurrent selection in self pollinated crops without extensive crossing. Crop Sci. 8 : 773.
16. Compton, W. A., and R.E. Comstock. 1976. More on modified ear-to-row selection. Crop Sci. 16 : 122.
17. Comstock, R. E. 1964. Selection procedures in corn improvement. p. 87-94. In Proc. Annu. Corn and Sorghum Res Conf., Chicago, IL. 9-10 Dec. Amer. Seed Trade Assoc., Washington, D.C.
18. Comstock, R. E. 1979. Inbred vs. the population as tester in reciprocal recurrent selection. Crop Sci. 19 (6): 881.

19. Comstock, R. E., H. F. Robinson, and P. H. Harvey. 1949. A breeding procedure designed to make maximum use of both general and specific combining ability. Agron. J. 41 : 360.

20. Coors, J. G. 1988. Response to four cycles of combined half-sib and S_1 family selection in maize. Crop Sci. 28 : 891.

21. Corriols, L. 1982. The different methods of breeding asparagus in France. Arch. Zuechtungsforsch 12 : 325.

22. Cress, P. E. 1966. Heterosis of the hybrid related to gene frequency difference between populations. Genetics 52 : 269.

23. Crisp, P. 1977. Breeding strategy for winter cauliflowers in South West Britain HortScience 52 : 347.

24. Crisp, P., A. R. Gray., H.James., J. M. Dudley, and S. Angell. 1981. Cauliflower and broccoli. Report National Vegetable Research Station 54.

25. Currah, L. 1985. Review of three onion improvement schemes in the tropics. Trop Agric. 62 : 131.

26. Cuthbert, F. P. J., and A. Jones. 1972. Resistance in sweet potatoes to *Coleoptera* increased by recurrent selection. J. Econ. Entomol. 65 : 1655.

27. Darrah, L. L., S. A. Eberhart, and L. H. Penny. 1972. Preliminary results from a maize breeding methods study in Kenya. Crop Sci. 12 : 605.

28. Darrah, L. L., S. A. Eberhart, and L. H. Penny. 1978. Six years of maize selection in " Kitale Synthetic II ", " Ecuador 573 " and " Kitale Composite A " using methods of the comprehensive breeding systems. Euphytica 27 : 191.

29. Dowker, B. D., A. R. A. Bowman, and G. J. Faulkner. 1971. The effect of selection during multiplication on the bolting resistance and internal quality of Avonearly red beet. J. Hortic. Sci. 46 : 307.

30. Dukes, P. D., A. Jones. and F. P. Jr. Cuthbert. 1975. Mass evaluation of sweet potato seedlings for reaction to *Fusarium wilt* and rootknot nematodes. Proc.Am. Phytopathol. Soc. 2 (Abstr.), 133.

31. Eberhart, S. A. 1972. Techniques and methods for more efficient population improvement in sorghum. Oxford University Press, Oxford, England. 197.

32. Eberhart, S. A., Seme Debela, and A. R. Hallauer. 1973. Reciprocal recurrent selection in the BSSS and BSCBI maize populations and half-sib selection in BSSS. Crop Sci. 13 : 451.

33. Falconer, D. S. 1981. Introduction to quantitative genetics. Longman Inc., New York.

34. Fehr, W. R. 1983. Applied plant breeding. Iowa state Univ. Ames. Iowa.

35. Fehr, W. R., and L. B. Ortiz. 1975. Recurrent selection for yield in soybeans.

J. Agric. Univ. P. R. 9 : 222.

36. Gardner, C. O. 1978. Population improvement in maize. p. 207. In walden, D. B. (ed.). Maize breeding and genetics. John Wiley and Sons, Inc. USA.

37. Gautney, T. L., and F. L. Haynes. 1983. Recurrent selection for heat tolerance in diploid potatoes *Solanum tuberosum* subsp. *phureja* and *stenotomum*. Am. Potato J. 60 : 537.

38. Gilbert, J. C. 1955. Pua-kea-cauliflower for low elevations. Hawaii Farm Sci. 4 (2) : 1.

39. Goulas, C. K.,and J. H. Lonnquist. 1976. Combined half-sib and S_1 family selection in a maize composite population. Crop Sci. 16 : 461.

40. Goulas, C. K., and J. H. Lonnquist. 1977. Comparison of combined half-sib and S_1 family selection with half-sib, S_1, and selection index procedures in maize. Crop Sci. 17 : 754.

41. Gray, A. R.,and P. Crisp. 1977. Breeding system, taxonomy and breeding strategy in cauliflower (*Brassica oleracea* var. *botrytis* L.). Euphytica 26 : 369.

42. Hallauer, A. R. 1967. Development of single-cross hybrids from twoeared maize populations. Crop Sci. 7 : 192.

43. Hallauer, A. R. 1984a. Reciprocal full-sib selection in maize. Crop Sci. 24 : 755.

44. Hallauer, A. R. 1984b. Compendium of recurrent selection methods and their application. CRC Critical Reviews in Plant Sci. 3 : 1.

45. Hallauer, A. R., and S. A. Eberhart. 1970. Reciprocal full-sib selection. Crop Sci. 12 : 315.

46. Hallauer, A. R., and J. B. Miranda. 1981. Quantitative genetics in maize breeding. Iowa state Univ. Press. Ames. Iowa.

47. Hayes, H. K., and R. J. Garber. 1919. Synthetic production of high protein corn in relation to breeding. J. Am. Soc. Agron. 11 : 308.

48. Hanson, W. D., and R. H. Moll. 1973. Experimental evaluations of relationships among populations resulting from intergradation among cultivars of *Zea mays* L. Genetics 73 : 133.

49. Hanson, W. D., and R. H. Moll. 1986. An analysis of changes in dominance-associated gene effects under intrapopulation and interpopulation selection in maize. Crop Sci. 26 : 268.

50. Hoard, K. G., and T. M. Crosbie. 1985. S_1-line recurrent selection for cold tolerance in two maize populations. Crop Sci. 25 : 1041.

51. Hoard, K. G., and T. M. Crosbie. 1986. Correlated Changes in agronomic traits from S_1-line recurrent selection for cold tolerance in two maize populations.

Crop Sci. 26 : 519.

52. Holland, H., and B. D. Dowker. 1969. The breeding of Avonearly, a red beet variety resistant to bolting. J. Hortic. Sci. 11 : 257.

53. Honma, S. 1965. Development and maintenance of uniformity in broccoli. J. Am. Soc. Hortic. Sci. 87 : 295.

54. Horne, F. R. 1954. Winter Cauliflower: history and breeding in the South West. Sci. Hortic. 11 : 128.

55. Horner, E. S., H. W. Lundy, M. C. Lutrick, and R. W. Wallane. 1963. Relative effectiveness of recurrent selection for specific combining ability in corn. Crop Sci. 3 : 63.

56. Hull, Fred H. 1945. Recurrent selection for specific combining ability in corn. J. Amer. Soc. Agron. 37 : 134.

57. Innes, N. L. 1982. The potential from plant breeding for vegetable crops. Sci. Hortic. 33 : 60.

58. Innes, N, L. 1983. Breeding field vegetables. Asian Vegetable Research and Development Center. Tainan. Taiwan. 34.

59. Jenkins, M.T. 1940. The segregation of genes affecting yield of grain in maize. J. Am. Soc. Agron. 32 : 55.

60. Jenkins, M. T. 1935. The effect of inbreeding and selection within inbred lines of maize upon the hybrids made after successive generations of selfing. Iowa State Coll. J. Sci. 9 : 429.

61. Jenkins, M. T., A. L. Robert, and W. R. Findley. 1954. Recurrent selection as a method for concentrating genes for resistance to *Helminthosporium turcicum* leaf blight in corn. Agron. Jour. 46 : 89.

62. Jinahyon, S., and W. A. Russell. 1969a. Evaluation of recurrent selection for stalk-rot resistance in an open-pollinated variety of maize. Iowa State Univ. J. Sci. 43 : 229.

63. Jinahyon, S., and W.A. Russell. 1969b. Effects of recurrent selection for stalk-rot resistance on other agronomic characters in an open-pollinated variety of maize. Iowa State Univ. J. Sci. 43 : 239.

64. Johnson, E. C., K. S. Fisher, G. O. Edmeades, and A. T. E. Palmer. 1986. Recurrent selection for reduced plant height in lowland tropical maize. Crop Sci. 26 : 253.

65. Johnston, T. D. 1981. Forage *Brassica* Breeding at the Welsh Plant Breeding Station. Welsh Plant Breeding Station Annu. Rep. 158.

66. Jones, A. 1965. A proposed breeding procedure for sweet potato. Crop Sci. 5 : 191.

67. Jones, A., D. P. Dukes, and F. P. Jr. Cuthbert. 1975. Mass selection in sweet potato : Breeding for resistance to insects and diseases and for horticultural characteristics. J. Am. Soc. Hortic. Sci. 101 : 701.

68. Jones, H. A., and L.K. Mann. 1963. Onions and their allies. Leonard Hill Books. Ltd., London.

69. Jones, A., J. M. Schalk, and D. P. Dukes. 1982. Progress in selection for resistance in sweet potato to soil insects of the WDS complex. In Proc. Ist. Int. Symp., Villareal, R. L. and Griggs, T. D., Eds., Asian Vegetable Research and Development Center, Tainan, Taiwan, 335.

70. Kalloo, Dr. 1988. Vegetable breeding. Volume I. CRC Press, Inc. Boca Raton, Florida.

71. Karffmann, K. D., and J. W. Dudley. 1979. Selection indices for corn grain yield, percent protein, and kernel weight. Crop Sci. 19 : 583.

72. Kenworthy, W. J., and C.A. Brim. 1979. Recurrent selection in soybeans. I. Seed yield. Crop Sci. 19 : 315.

73. Khotyleva, L. V., and A. V. Kil'chevskii. 1984. Efficacy of the first cycle of reciprocal recurrent selection based on an intervarietal tomato hybrid. Genetika 20 (9) : 1511.

74. Lambert, R.J. 1978. Breeding corn in a non-limiting environment. p.24. In Proc. Annu. Corn and Sorghum Res. Conf., Chicago. IL. 12-14 Dec. Amer. Seed Trade Assoc. Washington. D. C.

75. Lambert, R. J. 1984. Reciprocal recurrent selection of maize in a high-yield environment. Maydica 29 : 419.

76. Lertrat, K. 1985. Improving fruit yield in two pickling cucumber populations for a once-over mechanical harvesting system. Diss. Abstr. Int. B. 45(12), 3665 B.

77. Lertrat, K., and R. L. Lower. 1983. Pickling cucumber inbred line development by full-sib family selection(I). Rep. Cucurbit Genet. Coop. 6: 16.

78. Lertrat, K., and R.L. Lower. 1983. Pickling cucumber population improvement for increased fruit yields (I). Rep. Cucurbit Genet. Coop. 6 : 18.

79. Lertrat, K., and R. L. Lower. 1984. Pickling cucumber inbred line development by full-sib family selection (II). Rep. Cucurbit Genet. Coop. 7 : 8.

80. Lertrat, K., and R.L. Lower. 1984. Pickling cucumber population improvement for increased fruit yield (II). Rep. Cucurbit Genet. Coop. 7 : 9.

81. Li, C. C. 1978. First course in population genetics. Boxwood Press. Pacific Grove, California.

82. Lonnquist, J. H. 1964. Modification of the ear-to-row procedure for the impro-

vement of maize populations. Crop Sci. 4 : 227.

83. Lonquist, J. H., and D.P. McGill. 1956. Performance of corn synthetics in advanced generations of synthesis and after two cycles of recurrent selection. Agron. J. 48 : 249.
84. Lower, R. L. 1973. New vegetable varieties list XIX. HortScience 8 : 465.
85. Lower, R. L. 1975. New vegetable varieties list XX. HortScience 10 : 467.
86. Lower, R. L., and M. D. Edwards. 1986. Cucumber breeding p. 173. In Bassett, M. J. (ed.), Breeding vegetable crops. AVI Publishing Company, Inc. Westport, Connecticut, U. S. A.
87. Lower, R. L., and J. Nienhuis. 1985. Prospect for increasing yield in cucumber via *Cucumis sativus* var. *hardwickii* germplasm. In Biology and chemistry of the Cucurbitaceae. R. W. Robinson (ed.). Cornell Univ. Press, Ithaca, NY.
88. Lu, H. S., and R. J. Lambert. 1988. Response of two maize populations to recipr ocal recurrent selection in a high-yield environment. J. Agric. Res. China 37 (4) : 366.
89. Mareck, J. H., and C.O. Gardner. 1979. Responses to mass selection in maize and stability of resulting populations. Crop Sci. 19 : 779.
90. Marquez-Sanchez, F. 1982. Modifications to cyclic hybridization in maize with single-eared plants. Crop Sci. 22 : 314.
91. Martin, J. M., and A. R. Hallauer. 1980. Seven cycles of reciprocal recurrent selecion in BSSS and BSCBI maize populations. Crop Sci. 20 : 599.
92. Martin, M. J., and W. A. Russell. 1984a. Response of maize synthetic to recurrent selection for stalk quality. Crop Sci. 24 : 331.
93. Martin, M. J., and W. A. Russell. 1984b. Correlated response of yield and other agronomic traits to recurrent selection for stalk quality in maize synthetic. Crop Sci. 24 : 746.
94. McCollum, G. D. 1976. Onion and allies, in Evolution of Crop Plants. Simmonds, N. W., Ed., Longman. London. 186.
95. McGill, D. P., and J. H. Lonquist. 1955. Effect of two cycles of recurrent selection for combining ability in an open pollinated variety of corn. Agron. J. 47 : 319.
96. McNaughton, I. H. 1976. Swedes and rapes. In Evolution of Crop Plants, Simmonds, N. W., End. Longman. London. 53.
97. Melo, I. S., and C. P. Costa. 1983. Mass selection in a Pira Oura onion (*Allium cepa* L.) population for resistance to *Colletotrichum gloeosporioides*. Summa Phytopathol. 9 : 214.
98. Miles, J. W., J. W. Dudley, D. G. White, and R. J. Lambert.1980. Improving corn populations for grain yield and resistance to leaf blight and stalk rot. Crop

Sci. 20 : 247.

99. Miles, J. W., J. W. Dudley, D. G. White, and R. J. Lambert. 1981. Response to selection for resistance to four diseases in two corn populations. Crop Sci. 21 : 980.

100. Moll, R. H., C. C. Cockerham, C. W. Stuber, and W. P. Williams. 1978. Selection responses, genetic-environmental interaction, and heterosis with recurrent selection for yield in maize. Crop Sci. 18 : 641.

101. Moll, R. H., and W. D. Hanson. 1984. Comparison of effects of intrapopulation and interpopulation selection in maize (*Zea mays* L.). Crop Sci. 24 : 1047.

102. Moll, R. H., and H. F. Robinson. 1966. Observed and expected response in four selection experiments in maize. Crop Sci. 6 : 319.

103. Moll, R. H., and C. W. Stuber. 1971. Comparisons of response to alternative selection procedures initiated with two populations of maize (*Zea mays* L.). Crop Sci. 11 : 706.

104. National Academy of Science. 1972. Genetic vulnerability of major crops. NAS, Washington, DC.

105. Nicklow, C. W. 1983. The use of recurrent selection in efforts to achieve *Verticillium* resistance in eggplant. HortScience 18 (411) : 600.

106. Nienhuis, J. 1982. Response to different selection procedures for increased fruit yield in two pickling cucumber populations. Ph. D. Thesis. University of Wisconsin, Madison.

107. Opena, R. T., C. G. Kuo, and J. Y. Yoon. 1988. Breeding and seed production of Chinese cabbage in the tropics and subtropics. AVRDC Technical Bulletin 17: 35.

108. Opena, R. T., and S. H. Lo. 1979. Genetics of heat tolerance in heading Chinese cabbage . HortScience 14 : 33.

109. Parlevliet, J. E. 1968. Breeding for earliness in spinach (*Spinacia oleracea* L.) as based on environmental and genetic factors. Euphytica 17 : 21.

110. Paterniani, E. 1978. Reciprocal recurrent selection based on half-sib progenies and prolific plants in maize (*Zea mays* L.). Maydica 23 : 209.

111. Paterniani, E., and R. Vencovsky. 1977. Reciprocal recurrent selection in maize (*Zea mays* L.) based on testcrosses of half-sib families. Maydica 22 : 141.

112. Pecaut. P., H. Bannerot, and E. Berninger. 1983. Breeding varieties of vegetables and ornamental plants. C. R. Seances Acad. Agric. France 69 (15) : 1255.

113. Penny, L. H., W. A. Russell, and G. F. Sprague. 1962. Types of gene action in yield heterosis in maize. Crop Sci. 2 : 341.

114. Peterson, C. E. 1975. Plant introduction in the improvement of vegetable cultivars. HortScience 10 : 575.

115. Pyo, H. K. 1981. Historical observations on the cultivar development of Chinese cabbage in Korea. In Chinese cabbage Proc. Tainan, Taiwan, Asian Vegetable Research and Development Center. 41.

116. Rachie, K. O., K. Rawal, J. D. Pranckwiak, and M. A. Akinpeln. 1965. Two outcrossing mechanisms in cowpeas (*Vigna unguiculata* (L.) Walp.). Euphytica 24 : 159.

117. Ramanujam, S., and K. L. Sethi. 1975. Yield improvement by mass selection in Ajowan. Indian J. Genet. Plant. Breed. 35 : 327.

118. Russell, W. A., and S. A. Eberhart. 1975. Hybrid performance of selected maize lines from reciprocal recurrent selection testcross selection programs. Crop Sci. 15 : 1.

119. Russell, W. A., S. A. Eberhart. and Urbano A. Vega O. 1973. Recurrent selection for specific combining ability in two maize populations. Crop Sci. 13 : 256.

120. Ryder, E. J. 1979. Lettuce in leafy salad vegetables. AVI Publishing, Westport, Conn. 13.

121. Ryder, E. J., N. E. de Vos, and M. A. Bari. 1983. The globe artichoke (*Cynara scolymus* L.). HortScience 18 : 646.

122. Smith, O. S. 1983. Evaluation of recurrent selection in BSSS, BSCBI, and BS 13 maize populations. Crop Sci. 23 : 35.

123. Smith, O. S., R. L. Lower, and R. H. Moll. 1978. Estimates of heritabilities and variance components in pickling cucumber. J. Amer. Soc. Hort. Sci. 103:222.

124. Sprague, G. F. 1954. Breeding for resistance to stalk rot. p.33-43. In Proc. Annu. Hybrid Corn and Sorghum Ref. Conf., chicago, IL.1-2 Dec. Amer. Seed Trade Assoc., Washington, D. C.

125. Sprague, G. F. 1977. Corn and corn improvement. American Society Agronomists, Madison, Wisconsin.

126. Sprague, G. F., W. A. Russell, and L. H. Penny. 1959. Recurrent selection for specific combining ability and type of gene action involved in yield heterosis in corn. Agron. J. 51 : 392.

127. Strefeler, M. S. and T. C. Wehner. 1985. Estimates of genetic variances and covariances of three fresh-market cucumber populations. Cucurbit Genetics Cooperative Report 8 : 26.

128. Sullivan, J. G., and F. A Bliss. 1983. Recurrent mass selection for increased seed yield and seed protein percentage in the common bean (*Phaseolus vulgaris* L.) using a selection index. J. Am. Soc. Hortic. Sci. 108 : 42.

129. Swarup, V. 1977. Breeding procedures for cross-pollinated vegetable crops. Indian Council of Agricultural Research, New Delhi.

130. Thompson, D. L. 1969. Selection for stalk quality in corn. P. 7-14. In Proc. Annu. Corn and Sorghum Res. Conf., Chicago, IL. 9-11 Dec. Amer. Seed Trade Assoc., Washington, D. C.

131. Thompson, D. L. 1972. Recurrent selection for lodging susceptability and resistance in corn. Crop Sci. 12 : 631.

132. Thompson, D. L. 1982. Grain yield of two synthetics of corn after seven cycles of selection for lodging resistance. Crop Sci. 22 : 1207.

133. Tulupova, A. A. 1981. Method for the rapid breeding of cabbage. Kartofel Ovoshchi 12 : 18.

134. Walejko, R. N., and W. A. Russell. 1977. Evaluation of recurrent selection for specific combining ability in two open-pollinated maize cultivars. Crop Sci. 17 : 647.

135. Watts, L. E. 1960. The use of new technique in breeding for solidarity in radish. J. Hortic. Sci. 35 : 221.

136. Whitaker, T. W. 1979. The breeding of vegetable crops. Highlights of the past seventy-five years. HortScience 14 : 359.

137. Yoon, J. Y., and S. S. Lee. 1981. Considerations for breeding Chinese cabbage for summer conditions in Korea. In Chinese cabbage. Proc. 1st Int. Symp., Asian Vegetable Research and Development Center. Tainan. Taiwan. 443.

138. Yoon, J. Y., and R. T. Opena. 1977. Residual genetic variances on two Chinese cabbage populations after one cycle of recurrent selection. Korean J. Breeding 8 : 156.